NBS REPORT
10 760

FORTY-SEVENTH PROGRESS REPORT

to W-13,300

National Aeronautics and Space Administration

on

Cryogenic Research and Development

Period Ending September 30, 1972

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
Institute for Basic Standards
Boulder, Colorado 80302

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.
[4] Part of the Center for Building Technology.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
27500-2750400 27505-2750550	September 30, 1972	10 760

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Item Number	TASK ↓ / PHASE OF TASK →	Active Coord. with Lewis, MSFC, LASL	Not Started	Preliminary Planning	Apparatus Designing	Apparatus Construction	Data Taking	Data Analysis	Report Composition	Report in Press	Est. Completion Date	For Latest Report or Publication on This Task See: Quart. Report #	page	item #	Provisional (P) or Final (F)	Task Completed
1.	Slush Hydrogen															
	Heat Transfer (small scale)									x	10/30/72	45	2			
	Heat Transfer and Mixing				x	x					6/30/73	44	3			
	Hydrocarbon Suspension									x	10/30/72	45	9			
2.	Solid Hydrogen Studies					x					6/30/73	46	4			
3.	Consultation & Advisory Services										*	46	7			
3.1	MSFC Slush H_2 Flow Facility	x									*	46	7			

* continuing effort

1. Slush Hydrogen Heat Transfer and Hydrocarbon Suspension

1.0 General Comments

During this reporting period, editorial review of the final report on the hydrocarbon suspension work and the small laboratory scale slush heat transfer work was completed. Preliminary work has started on the larger laboratory scale heat transfer and mixing apparatus.

Personnel contributing to the program during this reporting period were C. Sindt and J. Hord.

1.1 Slush Hydrogen Heat Transfer and Mixing

The 1 m^3 vessel that is to be used for the heat transfer and mixing studies has been removed from the existing system; it is being disassembled so that the necessary modifications and instrumentation can be added. The existing transfer lines, slush generator, and instrumentation are being refurbished. Designs for the mixers and for the heat transfer instrumentation are continuing and are approximately one-fourth completed.

2. Solid Hydrogen Studies

2.0 General Comments

No work was performed on this task during the quarter. Due to the extended period of performance now in effect on this contract, and the increased emphasis on certain aspects of the consultation activities (Section 3), personnel have been temporarily reassigned to more urgent jobs and will not resume work on this task until March 1973.

3. Consultation and Advisory Services

3.0 General Comments

Contributing personnel were J. E. Cruz, J. Hord, P. R. Ludtke, D. B. Mann, R. D. McCarty, P. M. McConnell, R. J. Richards, H. M. Roder, N. Sanchez, A. F. Schmidt, C. F. Sindt, and G. H. Wallace.

3.1 MSFC Slush Hydrogen Flow Facility

Consultation on various areas of the NASA-MSFC Slush Hydrogen Flow Facility has been provided throughout this reporting period. On July 19-20, E. H. Hyde visited NBS-Boulder to discuss instrumentation and the test program proposed for the MSFC facility. The test program submitted in the previous quarter has been expanded and revised as requested by Mr. Hyde. An analysis of the agitator (stirring device) in the slush facility weigh vessel was also prepared. A detailed list of submissions to NASA-MSFC during the quarter follows:

7/12/72 - Slush Production in the MSFC Generator Using the Freeze-Thaw Method (3 pp).

8/14/72 - MSFC Slush Hydrogen Flow Facility Diagnostic Instrumentation Chart (6 copies).

8/17/72 - MSFC Slush Hydrogen Generator Ferromagnetic Rotary Feedthrough (1 p).

8/25/72 - Analysis of the Agitator in the Weigh Vessel of the MSFC Slush Hydrogen Flow Facility (20 pp).

9/ 7/72 - Information on the General Radio Type 1683 Bridge for the MSFC Slush Hydrogen Flow Facility (2 pp).

9/11/72 - Preliminary Draft of the First 6 Sections of the Revised Test Program for the MSFC Slush Hydrogen Flow Facility (58 pp).

9/14/72 - Instructions for Speed Conversion of the MSFC Slush Stirring Motor (1 p).

9/29/72 - Report on the Thermal Cycling of the Bullseye Capacitors for the MSFC Slush Hydrogen Flow Facility (16 pp). [see Appendix for this report].

APPENDIX

Thermal Cycling of Bullseye Capacitors

by

Cryogenics Division
NBS-Institute for Basic Standards
Boulder, Colorado 80302

September 26, 1972

Four bullseye capacitors of five received from NASA were tested in liquid hydrogen to obtain precise capacitance values in three temperature ranges and to determine stability of the precision through repeated thermal cycling.

A movable test probe inside the cryostat mechanically supported each capacitor individually (see figures 1 and 2) so the measurements could be taken with the capacitor oriented horizontally in the three test conditions for the temperatures required. Measurements were taken with the capacitor completely immersed in liquid hydrogen for the liquid phase, then it was elevated to just above the liquid for the cold gas phase, and finally it was elevated 24 inches above its initial position for the warm gas phase. The capacitor was warmed to near room temperature in this position using a minimum flow of hydrogen gas. It was determined that capacitance values did not change as temperature of the capacitor warmed above 240 K, so a warmup temperature limit of about 256 K was chosen for all tests. The resulting set of three capacitance measurements comprised one thermal cycle and was repeated for approximately 30 cycles for each capacitor tested. (See attached data reduction printout.)

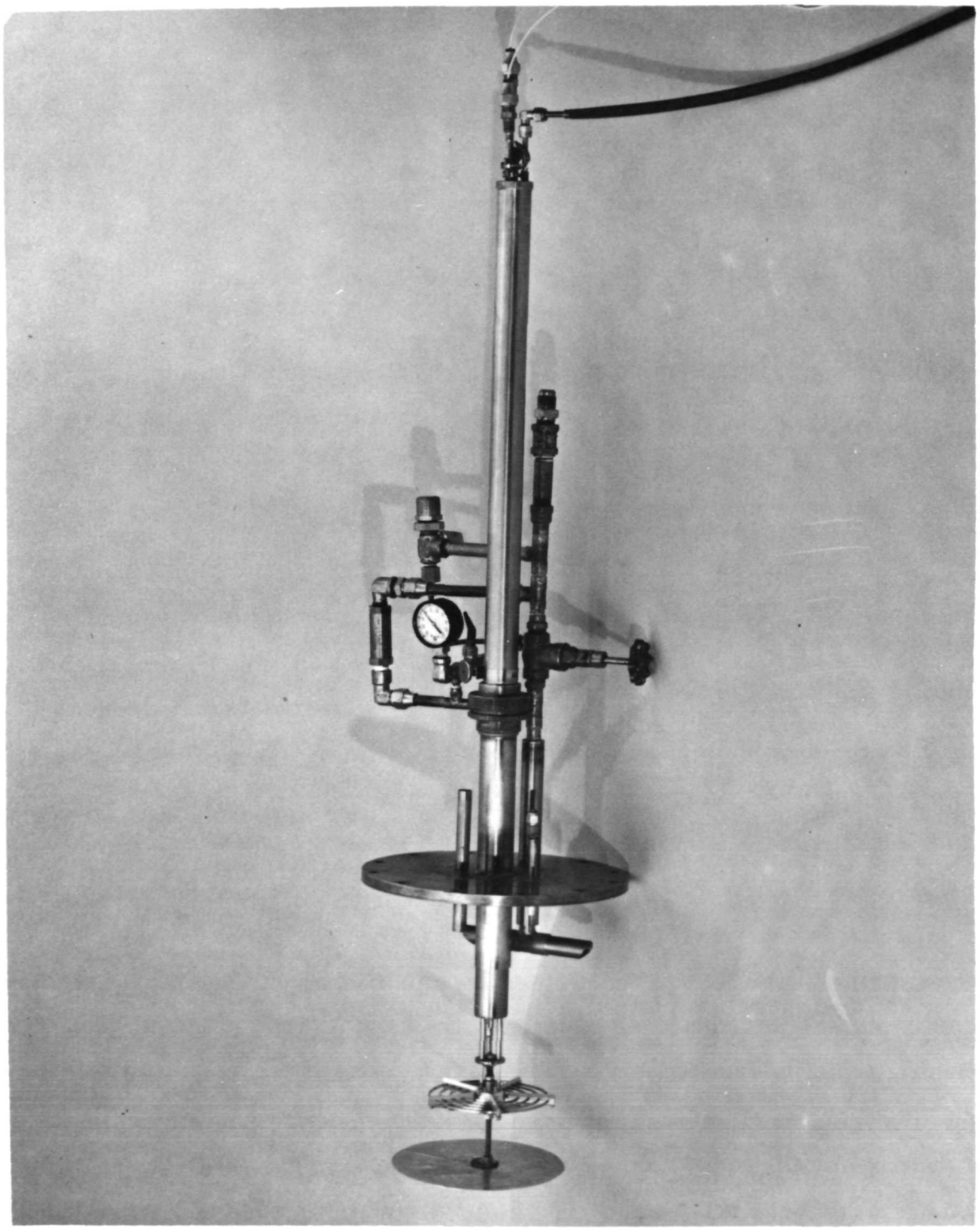

Figure 1. Bullseye Capacitor Thermal Cycle Test Probe.

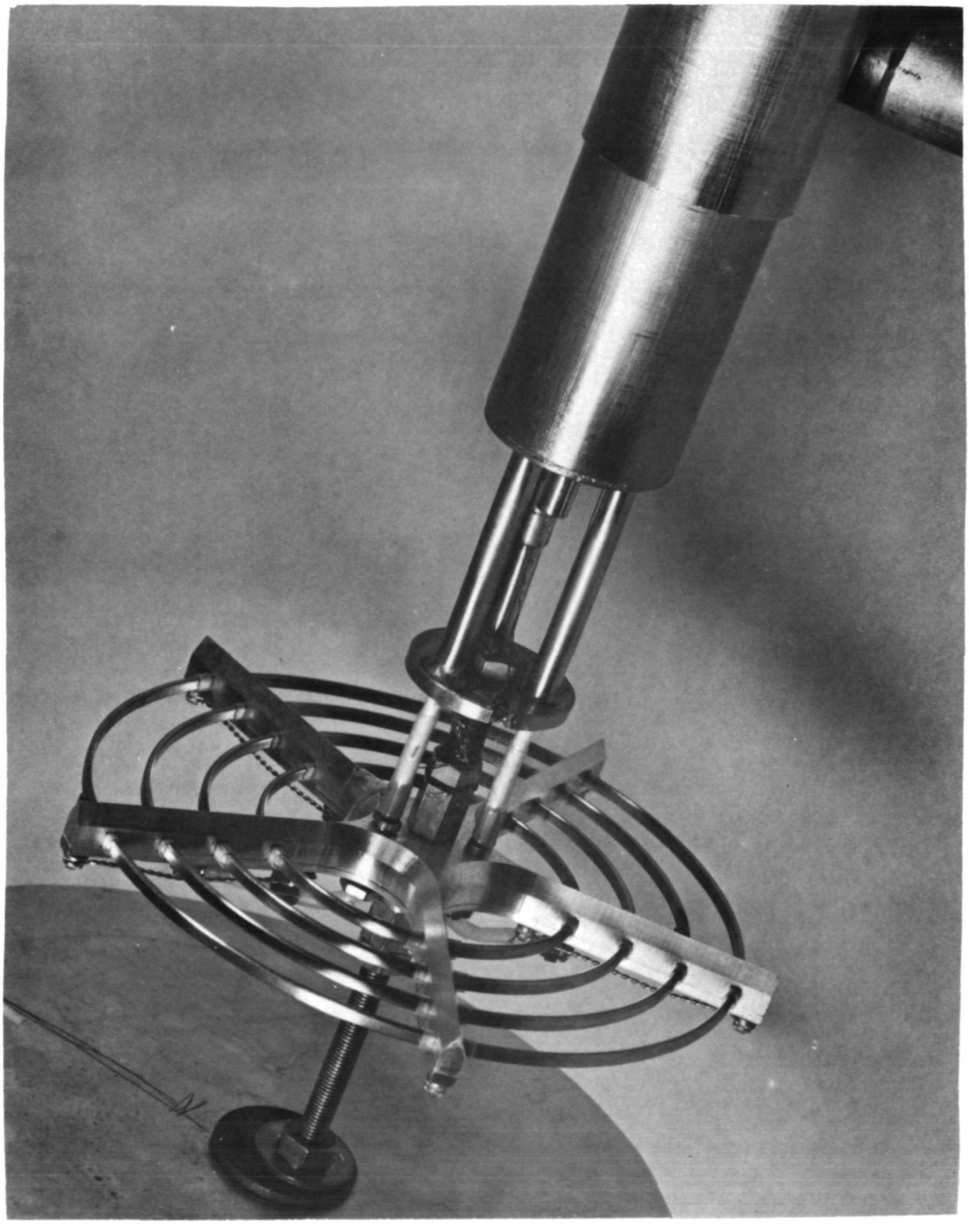

Figure 2. Bullseye Capacitor Thermal Cycle Test. Capacitor Mounting

Rigid mounting of the capacitor was accomplished by attaching the hex mounting screw to the center of a brass end plate which was soldered to the 1-1/2 inch O.D. stainless steel test probe. Four stainless steel tubes, each 1/4 inch O.D., were supported inside the length of the probe. Two of these provided support for the PTFE-insulated capacitor leads. They were sealed from air leak at the top by pulling the wires through rubber stoppers held in compression with flare fittings. One tube provided a conduit for the hydrogen warm-up gas while the fourth tube supported the thermocouple wires and was sealed from air leak at the top by a hot wax seal.

Since it was necessary to shield the capacitor from cold vapor during testing in the warm gas phase, a thin vapor barrier shield of 0.032 aluminum was attached to the center of the capacitor. Its distance was fixed at 3 inches below each unit tested. Capacitance values were not affected because of the fixed distance.

For the three test conditions, temperatures were monitored by a digital voltmeter for changes sensed by a Chromel-constantan thermocouple junction with an ice bath reference. The thermocouple junction was attached to one arm of the capacitor with glue and a winding of cotton thread. The wires were thermally tempered for the first twelve inches of their length by securing them in a winding around the hex mounting screw close to the junction. Temperatures of the liquid were calculated from vapor pressure data. Density was calculated as a function of temperature of the saturated liquid.

Capacitance values were measured with a sensitivity of one part in 10^5 pico-farads for the ranges required. Values of one part in 10^4 pf were taken for these tests.

A detailed statistical analysis by computer of the data array from all tests is presented on the following pages. A summary of the test data is shown in the table. Serial #1 was found to have a loose connecting wire and the data were not reported.

It must be noted that the absolute values of capacitance are a function of the particular test environment. These values may not reproduce under different mounting conditions. Also, the value change from cold gas to warm gas is not necessarily the geometry change of the capacitor caused by temperature change, but reflects in addition the change in the relative position of the capacitor and the top plate.

This work was performed under NASA Contract W-13, 300. R. J. Richards and G. H. Wallace conducted the experiment and wrote the report, and D. B. Mann contributed in analyses of data.

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 2
Liquid Hydrogen
T = 19.66 K
ρ = 71.4567 g/liter
P = 632.07 mm. Hg.

```
NUMBER OF VALUES = 32
NUMBER OF NONZERO WEIGHTS =     32
SUM OF WEIGHTS =   32
SUM OF UNWEIGHTED VALUES =      191.52
WEIGHTED MEAN =    5.985
UNWEIGHTED MEAN =     5.985
SMALLEST VALUE =   5.9833
LARGEST VALUE =    5.9876
RANGE =    .43E-02
WEIGHTED SUM OF SQUARES =    1146.247

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
      ESTIMATES FOR THE TOTAL POPULATION

VARIANCE =    .1337419E-05
STANDARD DEVIATION =      .1156468E-02
STANDARD ERROR OF MEAN =     .2044367E-03
COEFFICIENT OF VARIATION =      .1932278E-03
STUDENT'S T =    29275.57
MEAN SQUARE SUCCESSIVE DIFFERENCES =     .0712903E-05
(MEAN SQ SUCC DIFF)/(VARIANCE) =      .5330439
MEDIAN =      5.9849
NUMBER OF RUNS UP AND DOWN =    15
EXPECTED NUMBER OF RUNS =    21
STD ERROR OF NUMBER OF RUNS =     2.316606
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =    2.589995

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
 2 5 6 5 6 2 1 2 0 3

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS =     15
NUMBER OF - SIGNS IN DEVIATIONS =     17
NUMBER OF RUNS (SIGN CHANGES + 1) =      8
EXPECTED NUMBER OF RUNS =    16.9375
STD ERROR OF NUMBER OF RUNS =      2.771202
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     3.225135
TREND VALUE =   -.2012458E-04
STD ERROR OF TREND =      .4054208E-05
(TREND)/(STD ERROR) =    -4.963875
BETA ONE =    .6762469
BETA TWO =    2.999151
MEAN DEVIATION =    .888125E-02

RECAPITULATION OF INPUT:

VALUE          DEVIATIONS      WEIGHTS         ORDERED ARRAY

 5.9876          .26E-02          1              5.9833
 5.9875          .25E-02          1              5.9834
 5.9857          .07E-02          1              5.9838
 5.9852          .2000002E-03     1              5.9838
 5.9852          .2000002E-03     1              5.9838
 5.9843         -.07E-02          1              5.9839
 5.9838         -.12E-02          1              5.9841
 5.9843         -.07E-02          1              5.9842
 5.9838         -.12E-02          1              5.9842
 5.9839         -.11E-02          1              5.9842
 5.9842         -.08E-02          1              5.9843
 5.9849         -.0999997E-03     1              5.9843
 5.9851          .1000002E-03     1              5.9843
 5.9864          .14E-02          1              5.9847
 5.9875          .25E-02          1              5.9848
 5.9863          .13E-02          1              5.9849
 5.9842         -.08E-02          1              5.9849
 5.9834         -.16E-02          1              5.985
 5.9838         -.12E-02          1              5.9851
 5.9833         -.17E-02          1              5.9851
 5.9843         -.07E-02          1              5.9852
 5.9841         -.09E-02          1              5.9852
 5.9842         -.08E-02          1              5.9852
 5.9848         -.1999998E-03     1              5.9853
 5.9847         -.2999997E-03     1              5.9855
 5.9865          .15E-02          1              5.9857
 5.9853          .3000002E-03     1              5.9863
 5.9851          .1000002E-03     1              5.9864
 5.985           .2320306E-03     1              5.9865
 5.9849         -.2999997E-03     1              5.9875
 5.9855          .5000002E-03     1              5.9875
 5.9852          .2000002E-03     1              5.9876
```

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 2
Cold Hydrogen Gas
T ≈ 19.66 K

```
NUMBER OF VALUES = 32
NUMBER OF NONZERO WEIGHTS =     32
SUM OF WEIGHTS =   32
SUM OF UNWEIGHTED VALUES =      158.2547
WEIGHTED MEAN =    4.992959
UNWEIGHTED MEAN =     4.982959
SMALLEST VALUE =   4.98
LARGEST VALUE =    4.9916
RANGE =    .116E-01
WEIGHTED SUM OF SQUARES =   792.9855

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
      ESTIMATES FOR THE TOTAL POPULATION

VARIANCE =    .0776636E-04
STANDARD DEVIATION =       .2796819E-02
STANDARD ERROR OF MEAN =      .4926447E-03
COEFFICIENT OF VARIATION =       .5707233E-03
STUDENT'S T =    9911.727
MEAN SQUARE SUCCESSIVE DIFFERENCES =     .0722161E-04
(MEAN SQ SUCC DIFF)/(VARIANCE) =      .929858
MEDIAN =     4.99225
NUMBER OF RUNS UP AND DOWN =    19
EXPECTED NUMBER OF RUNS =    21
STD ERROR OF NUMBER OF RUNS =      2.316606
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =      .8633316

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
 9 9 3 6 1 0 2 1 0 1

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS =     11
NUMBER OF - SIGNS IN DEVIATIONS =     21
NUMBER OF RUNS (SIGN CHANGES + 1) =      11
EXPECTED NUMBER OF RUNS =    15.4375
STD ERROR OF NUMBER OF RUNS =      2.581638
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =      1.773838
TREND VALUE =   -.14342E-03
STD ERROR OF TREND =       .286721E-04
(TREND)/(STD ERROR) =    -16.53809
BETA ONE =    1.740098
BETA TWO =    4.484182
MEAN DEVIATION =    .2292429E-02

RECAPITULATION OF INPUT:

VALUE           DEVIATIONS      WEIGHTS         ORDERED ARRAY

 4.9916          .2864202E-01   1               4.98
 4.9874          .4442625E-02   1               4.98
 4.9877          .4742625E-02   1               4.98
 4.9935          .5406252E-03   1               4.9901
 4.9845          .1542625E-02   1               4.9902
 4.9928          -.1593748E-03  1               4.9902
 4.9818          -.1159374E-02  1               4.9905
 4.9911          -.1859375E-02  1               4.9908
 4.9818          -.1159374E-02  1               4.9911
 4.9928          -.1593748E-03  1               4.9912
 4.9922          -.2759375E-02  1               4.9915
 4.9812          -.1759374E-02  1               4.9918
 4.9915          -.1459375E-02  1               4.9918
 4.9922          -.2759375E-02  1               4.9921
 4.9928          -.1593748E-03  1               4.9922
 4.9923          -.2659375E-02  1               4.9922
 4.9887           .5742625E-02  1               4.9923
 4.9942           .1242625E-02  1               4.9923
 4.9902          -.2759375E-02  1               4.9928
 4.9921          -.3859375E-02  1               4.9928
 4.9944           .1442625E-02  1               4.9928
 4.9843           .1342625E-02  1               4.9935
 4.9908          -.2159375E-02  1               4.9941
 4.98            -.2959374E-02  1               4.9942
 4.9905          -.2459375E-02  1               4.9943
 4.98            -.2959374E-02  1               4.9944
 4.9856           .2642625E-02  1               4.9945
 4.9823          -.2659375E-02  1               4.9956
 4.98            -.2959374E-02  1               4.9974
 4.9941           .1142625E-02  1               4.9977
 4.9902          -.2759375E-02  1               4.9987
 4.9901          -.2859375E-02  1               4.9916
```

Bullseye Capacitor
S/N 2
Warm Hydrogen Gas
T ≈ 256 K

COMPUTATIONS ON THE DATA ARRAY:

NUMBER OF VALUES = 32
NUMBER OF NONZERO WEIGHTS = 32
SUM OF WEIGHTS = 32
SUM OF UNWEIGHTED VALUES = 156.9098
WEIGHTED MEAN = 4.903425
UNWEIGHTED MEAN = 4.903425
SMALLEST VALUE = 4.9006
LARGEST VALUE = 4.9068
RANGE = .62E-02
WEIGHTED SUM OF SQUARES = 769.3945

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
ESTIMATES FOR THE TOTAL POPULATION

VARIANCE = .2412903E-05
STANDARD DEVIATION = .1553352E-02
STANDARD ERROR OF MEAN = .2745965E-03
COEFFICIENT OF VARIATION = .3167092E-03
STUDENT'S T = 17856.84
MEAN SQUARE SUCCESSIVE DIFFERENCES = .1673225E-05
(MEAN SQ SUCC DIFF)/(VARIANCE) = .6934492
MEDIAN = 4.90315
NUMBER OF RUNS UP AND DOWN = 14
EXPECTED NUMBER OF RUNS = 21
STD ERROR OF NUMBER OF RUNS = 2.316606
(ACTUAL RUNS - EXP RUNS)/(STD ERR) = 3.02166

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
3 2 2 8 5 3 2 3 3 1

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS = 13
NUMBER OF - SIGNS IN DEVIATIONS = 19
NUMBER OF RUNS (SIGN CHANGES + 1) = 9
EXPECTED NUMBER OF RUNS = 16.4375
STD ERROR OF NUMBER OF RUNS = 2.68135
(ACTUAL RUNS - EXP RUNS)/(STD ERR) = 2.773788
TREND VALUE = .3954912E-03
STD ERROR OF TREND = .4509345E-05
(TREND)/(STD ERROR) = 21.17629
BETA ONE = .6652103
BETA TWO = 2.41786
MEAN DEVIATION = .1248437E-02

RECAPITULATION OF INPUT:

VALUE	DEVIATIONS	WEIGHTS	ORDERED ARRAY
4.9011	-.2325E-02	1	4.9006
4.9022	-.1225E-02	1	4.9009
4.9032	-.2249997E-03	1	4.9011
4.9027	-.9725E-02	1	4.9015
4.9033	-.1249998E-03	1	4.9018
4.9036	.1750002E-03	1	4.902
4.904	.5750002E-03	1	4.9022
4.9015	-.1925E-02	1	4.9026
4.9026	-.2825E-02	1	4.9026
4.9018	-.1525E-02	1	4.9027
4.9031	-.3249998E-03	1	4.9027
4.9039	.4750002E-03	1	4.9027
4.9032	-.2249997E-03	1	4.9029
4.9027	-.8725E-02	1	4.903
4.9029	-.5249998E-03	1	4.903
4.9026	-.0825E-02	1	4.9031
4.9027	-.0725E-02	1	4.9032
4.9009	-.2525E-02	1	4.9032
4.902	-.1425E-02	1	4.9033
4.9051	.1675E-02	1	4.9036
4.9054	.1975E-02	1	4.9039
4.9057	.2275E-02	1	4.904
4.9058	.2375E-02	1	4.9042
4.9026	-.0825E-02	1	4.9044
4.903	-.4249997E-03	1	4.9046
4.903	-.4249997E-03	1	4.9051
4.9059	.2475E-02	1	4.9051
4.9068	.3375E-02	1	4.9054
4.9051	.1675E-02	1	4.9057
4.9046	.1175E-02	1	4.9058
4.9044	.0975E-02	1	4.9059
4.9042	.0775E-02	1	4.9068

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 3
Liquid Hydrogen
T = 19.60 K
ρ = 71.5221 g/liter
P = 619.30 mm Hg.

```
NUMBER OF VALUES =  30
NUMBER OF NONZERO WEIGHTS =     30
SUM OF WEIGHTS =   30
SUM OF UNWEIGHTED VALUES =      179.4973
WEIGHTED MEAN =    5.983243
UNWEIGHTED MEAN =     5.983243
SMALLEST VALUE =   5.9822
LARGEST VALUE =    5.9853
RANGE =    .31E-02
WEIGHTED SUM OF SQUARES =    1073.976

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
      ESTIMATES FOR THE TOTAL POPULATION

VARIANCE =    .0778402E-05
STANDARD DEVIATION =      .8882271E-02
STANDARD ERROR OF MEAN =     .1618799E-03
COEFFICIENT OF VARIATION =      .147457E-03
STUDENT'S T =    37144.56
MEAN SQUARE SUCCESSIVE DIFFERENCES =     .0786287E-05
(MEAN SQ SUCC DIFF)/(VARIANCE) =      1.010026
MEDIAN =     5.98305
NUMBER OF RUNS UP AND DOWN =    13
EXPECTED NUMBER OF RUNS =    19.66667
STD ERROR OF NUMBER OF RUNS =     2.238551
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     2.978117

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
 8 5 4 2 1 4 3 0 2 1

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS =     12
NUMBER OF - SIGNS IN DEVIATIONS =     18
NUMBER OF RUNS (SIGN CHANGES + 1) =      9
EXPECTED NUMBER OF RUNS =    15.4
STD ERROR OF NUMBER OF RUNS =     2.579494
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     2.481186
TREND VALUE =    .4249219E-05
STD ERROR OF TREND =      .3576864E-05
(TREND)/(STD ERROR) =     1.188247
BETA ONE =    .3913696
BETA TWO =    2.34735
MEAN DEVIATION =    .0745333E-02

RECAPITULATION OF INPUT:
```

VALUE	DEVIATIONS	WEIGHTS	ORDERED ARRAY
5.9826	-.0643333E-02	1	5.9822
5.9841	.8856666E-02	1	5.9822
5.9838	.5566669E-03	1	5.9822
5.9836	.3566669E-03	1	5.9823
5.993	-.243333E-03	1	5.9823
5.9831	-.1433331E-03	1	5.9824
5.9842	.8956666E-02	1	5.9824
5.994	.8756666E-02	1	5.9825
5.9831	-.1433331E-03	1	5.9826
5.983	-.243333E-03	1	5.9826
5.9825	-.8743333E-02	1	5.9827
5.9827	-.5433331E-03	1	5.9827
5.9827	-.5433331E-03	1	5.9827
5.9823	-.8043333E-02	1	5.983
5.9824	-.7943333E-02	1	5.993
5.9823	-.8943333E-02	1	5.9831
5.9824	-.7943333E-02	1	5.9831
5.9834	.1566669E-03	1	5.9832
5.9853	.2056666E-02	1	5.9834
5.994	.8756666E-02	1	5.9836
5.9848	.1556666E-02	1	5.9838
5.9822	-.1043333E-02	1	5.9839
5.9827	-.5433331E-03	1	5.984
5.9832	-.4333307E-04	1	5.984
5.9822	-.1043333E-02	1	5.9841
5.9822	-.1043333E-02	1	5.9842
5.9826	-.0643333E-02	1	5.9842
5.9839	.8656666E-02	1	5.9848
5.9842	.8956666E-02	1	5.9848
5.9848	.1556666E-02	1	5.9853

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 3
Cold Hydrogen Gas
T ≈ 19.6 K

```
NUMBER OF VALUES = 29
NUMBER OF NONZERO WEIGHTS =     29
SUM OF WEIGHTS =   29
SUM OF UNWEIGHTED VALUES =      141.3632
WEIGHTED MEAN =    4.874593
UNWEIGHTED MEAN =      4.874593
SMALLEST VALUE =   4.8655
LARGEST VALUE =    4.8844
RANGE =    .199E-01
WEIGHTED SUM OF SQUARES =    689.0884

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
      ESTIMATES FOR THE TOTAL POPULATION

VARIANCE =    .1177281E-04
STANDARD DEVIATION =      .3431153E-02
STANDARD ERROR OF MEAN =      .9637149E-02
COEFFICIENT OF VARIATION =      .0703884E-02
STUDENT'S T =    7650.532
MEAN SQUARE SUCCESSIVE DIFFERENCES =     .1097535E-04
(MEAN SQ SUCC DIFF)/(VARIANCE) =      .9322633
MEDIAN =      4.8741
NUMBER OF RUNS UP AND DOWN =    14
EXPECTED NUMBER OF RUNS =    19
STD ERROR OF NUMBER OF RUNS =      2.198484
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     2.274294

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
 1 0 1 5 12 5 3 0 1 1

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS =     12
NUMBER OF - SIGNS IN DEVIATIONS =     17
NUMBER OF RUNS (SIGN CHANGES + 1) =      10
EXPECTED NUMBER OF RUNS =    15.06897
STD ERROR OF NUMBER OF RUNS =      2.562661
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     1.978092
TREND VALUE =   -.1921178E-04
STD ERROR OF TREND =      .1498778E-04
(TREND)/(STD ERROR) =    -1.288708
BETA ONE =    .2451505
BETA TWO =    5.33219
MEAN DEVIATION =    .2288466E-02

RECAPITULATION OF INPUT:
```

VALUE	DEVIATIONS	WEIGHTS	ORDERED ARRAY
4.8655	-.0090931E-01	1	4.8655
4.8725	-.2093103E-02	1	4.8703
4.8754	.0006896E-02	1	4.8716
4.8723	-.2293103E-02	1	4.8722
4.8738	-.0793103E-02	1	4.8723
4.8741	-.4931033E-03	1	4.8724
4.8716	-.2993103E-02	1	4.8725
4.882	.074069E-01	1	4.8731
4.8844	.098069E-01	1	4.8732
4.8781	.3506896E-02	1	4.8732
4.8775	.2906896E-02	1	4.8737
4.8777	.3106896E-02	1	4.8738
4.8756	.1006897E-02	1	4.8741
4.8741	-.4931033E-03	1	4.8741
4.8741	-.4931033E-03	1	4.8741
4.8731	-.1493103E-02	1	4.8743
4.8766	.2006896E-02	1	4.8745
4.8743	-.2931032E-03	1	4.8746
4.8737	-.0893103E-02	1	4.8749
4.8732	-.1393103E-02	1	4.875
4.8703	-.4293103E-02	1	4.8754
4.8765	.1906896E-02	1	4.8756
4.875	.4068967E-03	1	4.8765
4.8746	.0689673E-04	1	4.8766
4.8749	.3068967E-03	1	4.8775
4.8745	-.0931032E-03	1	4.8777
4.8732	-.1393103E-02	1	4.8781
4.8724	-.2193103E-02	1	4.882
4.8722	-.2393103E-02	1	4.8844

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 3
Warm Hydrogen Gas
T ≈ 256 K

```
NUMBER OF VALUES = 30
NUMBER OF NONZERO WEIGHTS =     30
SUM OF WEIGHTS =    30
SUM OF UNWEIGHTED VALUES =      146.6662
WEIGHTED MEAN =     4.998873
UNWEIGHTED MEAN =      4.988873
SMALLEST VALUE =    4.9881
LARGEST VALUE =     4.99
RANGE =     .19E-02
WEIGHTED SUM OF SQUARES =    717.0325

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
      ESTIMATES FOR THE TOTAL POPULATION

VARIANCE =     .1537471E-06
STANDARD DEVIATION =       .392106E-03
STANDARD ERROR OF MEAN =      .7715884E-03
COEFFICIENT OF VARIATION =       .0992038E-03
STUDENT'S T =    68291.39
MEAN SQUARE SUCCESSIVE DIFFERENCES =     .2258621E-06
(MEAN SQ SUCC DIFF)/(VARIANCE) =      1.469849
MEDIAN =      4.9989
NUMBER OF RUNS UP AND DOWN =    23
EXPECTED NUMBER OF RUNS =    19.66667
STD ERROR OF NUMBER OF RUNS =      2.238851
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =      1.489858

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
 1 2 6 5 6 8 0 0 1 1

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS =     16
NUMBER OF - SIGNS IN DEVIATIONS =     14
NUMBER OF RUNS (SIGN CHANGES + 1) =      8
EXPECTED NUMBER OF RUNS =    15.93333
STD ERROR OF NUMBER OF RUNS =      2.678594
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     2.961752
TREND VALUE =    -.155728E-04
STD ERROR OF TREND =      .1492327E-05
(TREND)/(STD ERROR) =    -10.44926
BETA ONE =     .4835431
BETA TWO =     4.000665
MEAN DEVIATION =     .3017778E-03

RECAPITULATION OF INPUT:

VALUE          DEVIATIONS       WEIGHTS        ORDERED ARRAY

 4.8897         .0826666E-02    1              4.8881
 4.8889         .2666694E-04    1              4.8883
 4.8891         .2266669E-03    1              4.8884
 4.8889         .2666694E-04    1              4.8885
 4.8892         .3266669E-03    1              4.8885
 4.8891         .2266669E-03    1              4.8886
 4.8891         .2266669E-03    1              4.8888
 4.89           .1126666E-02    1              4.8888
 4.889          .1266669E-03    1              4.8886
 4.8891         .2266669E-03    1              4.8887
 4.9884        -.4733331E-03    1              4.8887
 4.8887        -.173333E-03     1              4.8887
 4.8886        -.2733331E-03    1              4.8887
 4.8885        -.373333E-03     1              4.8887
 4.8886        -.2733331E-03    1              4.8889
 4.8887        -.173333E-03     1              4.8889
 4.8885        -.373333E-03     1              4.9988
 4.8887        -.173333E-03     1              4.889
 4.8886        -.2733331E-03    1              4.889
 4.8887        -.173333E-03     1              4.889
 4.8881        -.0773333E-02    1              4.8891
 4.8892         .3265669E-03    1              4.8891
 4.889          .1266669E-03    1              4.9891
 4.8887        -.173333E-03     1              4.8891
 4.8886        -.2733331E-03    1              4.9891
 4.8891         .2266669E-03    1              4.8892
 4.8883        -.573333E-03     1              4.8892
 4.889          .1266669E-03    1              4.9892
 4.8889         .2666694E-04    1              4.9897
 4.8892         .3266669E-03    1              4.89
```

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 4
Liquid Hydrogen
T = 19.63 K
ρ = 71.4895 g/liter
P = 625.93 mm. Hg.

```
NUMBER OF VALUES = 31
NUMBER OF NONZERO WEIGHTS =     31
SUM OF WEIGHTS =   31
SUM OF UNWEIGHTED VALUES =      186.4625
WEIGHTED MEAN =    5.982661
UNWEIGHTED MEAN =      5.982661
SMALLEST VALUE =   5.9802
LARGEST VALUE =    5.9848
RANGE =    .46E-02
WEIGHTED SUM OF SQUARES =    1109.559

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
      ESTIMATES FOR THE TOTAL POPULATION

VARIANCE =    .1399784E-05
STANDARD DEVIATION =      .1178891E-02
STANDARD ERROR OF MEAN =     .2117351E-03
COEFFICIENT OF VARIATION =      .1970513E-03
STUDENT'S T =    28255.4
MEAN SQUARE SUCCESSIVE DIFFERENCES =     .1363333E-05
(MEAN SQ SUCC DIFF)/(VARIANCE) =      .9809671
MEDIAN =      5.9826
NUMBER OF RUNS UP AND DOWN =    19
EXPECTED NUMBER OF RUNS =    20.33333
STD ERROR OF NUMBER OF RUNS =      2.277913
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     .585331

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
 1 2 1 6 3 8 2 2 2 4

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS =     13
NUMBER OF - SIGNS IN DEVIATIONS =     18
NUMBER OF RUNS (SIGN CHANGES + 1) =      11
EXPECTED NUMBER OF RUNS =    16.09677
STD ERROR OF NUMBER OF RUNS =      2.66343
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     1.913612
TREND VALUE =    .2681457E-04
STD ERROR OF TREND =      .4374486E-05
(TREND)/(STD ERROR) =     6.129877
BETA ONE =    .2559471E-01
BETA TWO =    2.500877
MEAN DEVIATION =    .0003434E-02

RECAPITULATION OF INPUT:

VALUE          DEVIATIONS      WEIGHTS        ORDERED ARRAY

 5.9802         -.246129E-02     1              5.9802
 5.9809         -.176129E-02     1              5.9808
 5.9816         -.106129E-02     1              5.9809
 5.982          -.066129E-02     1              5.9814
 5.9827          .3870995E-04    1              5.9816
 5.9827          .3870995E-04    1              5.9816
 5.9836          .0938709E-02    1              5.9819
 5.9844          .173871E-02     1              5.982
 5.9848          .2138709E-02    1              5.982
 5.9841          .1438709E-02    1              5.982
 5.9848          .2138709E-02    1              5.9821
 5.9822         -.46129E-03      1              5.9822
 5.9808         -.186129E-02     1              5.9824
 5.9819         -.076129E-02     1              5.9825
 5.9814         -.126129E-02     1              5.9825
 5.982          -.066129E-02     1              5.9826
 5.9846          .193871E-02     1              5.9826
 5.9816         -.106129E-02     1              5.9826
 5.9826         -.6129005E-04    1              5.9827
 5.9821         -.56129E-03      1              5.9827
 5.9825         -.16129E-03      1              5.9828
 5.9826         -.6129005E-04    1              5.983
 5.9824         -.2612901E-03    1              5.9832
 5.9825         -.16129E-03      1              5.9836
 5.9828          .1387099E-03    1              5.9838
 5.9826         -.6129005E-04    1              5.9841
 5.9841          .1438709E-02    1              5.9841
 5.982          -.066129E-02     1              5.9844
 5.9832          .5387099E-03    1              5.9846
 5.983           .3387099E-03    1              5.9848
 5.9838          .113871E-02     1              5.9848
```

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 4
Cold Hydrogen Gas
T ≈ 19.63 K

NUMBER OF VALUES = 31
NUMBER OF NONZERO WEIGHTS = 31
SUM OF WEIGHTS = 31
SUM OF UNWEIGHTED VALUES = 151.1948
WEIGHTED MEAN = 4.877251
UNWEIGHTED MEAN = 4.877251
SMALLEST VALUE = 4.9746
LARGEST VALUE = 4.9803
RANGE = .57E-02
WEIGHTED SUM OF SQUARES = 737.4151

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY ESTIMATES FOR THE TOTAL POPULATION

VARIANCE = .194258E-05
STANDARD DEVIATION = .1393764E-02
STANDARD ERROR OF MEAN = .2503276E-03
COEFFICIENT OF VARIATION = .2857885E-03
STUDENT'S T = 19483.48
MEAN SQUARE SUCCESSIVE DIFFERENCES = .1833667E-05
(MEAN SQ SUCC DIFF)/(VARIANCE) = .9439333
MEDIAN = 4.9772
NUMBER OF RUNS UP AND DOWN = 14
EXPECTED NUMBER OF RUNS = 20.33333
STD ERROR OF NUMBER OF RUNS = 2.277913
(ACTUAL RUNS - EXP RUNS)/(STD ERR) = 2.780322

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
2 2 4 4 6 6 1 3 1 2

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS = 13
NUMBER OF - SIGNS IN DEVIATIONS = 18
NUMBER OF RUNS (SIGN CHANGES + 1) = 13
EXPECTED NUMBER OF RUNS = 16.09677
STD ERROR OF NUMBER OF RUNS = 2.66343
(ACTUAL RUNS - EXP RUNS)/(STD ERR) = 1.162791
TREND VALUE = -.5165318E-04
STD ERROR OF TREND = .4976967E-05
(TREND)/(STD ERROR) = -10.37865
BETA ONE = .5945ECE-01
BETA TWO = 2.832729
MEAN DEVIATION = .1059937E-02

RECAPITULATION OF INPUT:

VALUE	DEVIATIONS	WEIGHTS	ORDERED ARRAY
4.8803	.3048387E-02	1	4.9746
4.9777	.4483872E-03	1	4.8746
4.877	-.2516127E-03	1	4.8755
4.8776	.3483873E-03	1	4.8756
4.9756	-.1651613E-02	1	4.8759
4.9772	-.516127E-04	1	4.9762
4.9777	.4483872E-03	1	4.8762
4.8764	-.8951612E-02	1	4.8763
4.8763	-.8951612E-02	1	4.8764
4.877	-.2516127E-03	1	4.8767
4.8762	-.1051613E-02	1	4.8767
4.8768	-.4516128E-03	1	4.8768
4.8789	.1648387E-02	1	4.877
4.8794	.2148387E-02	1	4.877
4.8782	.8948387E-02	1	4.877
4.8767	-.5516127E-03	1	4.8772
4.879	.1748387E-02	1	4.9772
4.8799	.2648387E-02	1	4.8772
4.879	.1748387E-02	1	4.8775
4.8778	.5483873E-03	1	4.9776
4.8777	.4483872E-03	1	4.8777
4.8767	-.5516127E-03	1	4.8777
4.8759	-.1351612E-02	1	4.9777
4.8772	-.516127E-04	1	4.9778
4.8772	-.516127E-04	1	4.8782
4.8746	-.2651612E-02	1	4.9799
4.8776	.2483872E-03	1	4.879
4.877	-.2516127E-03	1	4.879
4.8762	-.1051613E-02	1	4.9794
4.8755	-.1751613E-02	1	4.9799
4.8748	-.2851612E-02	1	4.8803

COMPUTATIONS ON THE DATA ARRAY:

Bullseye Capacitor
S/N 4
Warm Hydrogen Gas
T ≈ 256 K

```
NUMBER OF VALUES = 31
NUMBER OF NONZERO WEIGHTS =     31
SUM OF WEIGHTS =   31
SUM OF UNWEIGHTED VALUES =      151.7362
WEIGHTED MEAN =    4.894716
UNWEIGHTED MEAN =      4.894716
SMALLEST VALUE =   4.892
LARGEST VALUE =    4.8988
RANGE =    .068E-01
WEIGHTED SUM OF SQUARES =   742.7057

NOTE: THE FOLLOWING MEASURES PERTAIN TO THE MOST-LIKELY
      ESTIMATES FOR THE TOTAL POPULATION

VARIANCE =    .2708064E-05
STANDARD DEVIATION =       .164562E-02
STANDARD ERROR OF MEAN =     .295562E-03
COEFFICIENT OF VARIATION =      .3362033E-03
STUDENT'S T =    16562.7
MEAN SQUARE SUCCESSIVE DIFFERENCES =     .1072667E-05
(MEAN SQ SUCC DIFF)/(VARIANCE) =      .3961809
MEDIAN =      4.8945
NUMBER OF RUNS UP AND DOWN =    12
EXPECTED NUMBER OF RUNS =    20.33333
STD ERROR OF NUMBER OF RUNS =      2.277913
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     3.658319

FREQUENCY DISTRIBUTION (TEN EQUAL CLASSES):
 2 5 3 10 3 1 3 2 0 2

COMPUTATIONS ON DEVIATIONS FROM MEAN:

NUMBER OF + SIGNS IN DEVIATIONS =     11
NUMBER OF - SIGNS IN DEVIATIONS =     20
NUMBER OF RUNS (SIGN CHANGES + 1) =      10
EXPECTED NUMBER OF RUNS =    15.19354
STD ERROR OF NUMBER OF RUNS =      2.498421
(ACTUAL RUNS - EXP RUNS)/(STD ERR) =     2.078732
TREND VALUE =   -.4665319E-04
STD ERROR OF TREND =      .6332276E-05
(TREND)/(STD ERROR) =    -7.736493
BETA ONE =    .6300196
BETA TWO =    3.3269e2
MEAN DEVIATION =    .1227263E-02

RECAPITULATION OF INPUT:

VALUE          DEVIATIONS      WEIGHTS        ORDERED ARRAY

 4.892         -.2716129E-02   1              4.892
 4.893         -.1716129E-02   1               4.9923
 4.9946        -.1161288E-03   1               4.9929
 4.9961         .1383871E-02   1               4.993
 4.8971         .2383871E-02   1               4.9932
 4.8986         .3983871E-02   1               4.9932
 4.8988         .4083871E-02   1               4.9933
 4.8961         .1383871E-02   1               4.9936
 4.9936         .1883871E-02   1               4.9936
 4.9969         .2183871E-02   1               4.9937
 4.9956         .0983871E-02   1               4.9942
 4.9929        -.1816129E-02   1               4.9943
 4.9923        -.2416129E-02   1               4.9944
 4.9932        -.1516129E-02   1               4.9944
 4.9933        -.1416129E-02   1               4.9944
 4.9936        -.1116129E-02   1               4.9945
 4.8936        -.1116129E-02   1               4.9945
 4.9946        -.1161288E-03   1               4.9946
 4.9937        -.1016129E-02   1               4.9946
 4.8943        -.4161289E-03   1               4.8946
 4.8944        -.3161288E-03   1               4.8949
 4.8945        -.2161289E-03   1               4.8949
 4.8949         .1838711E-03   1               4.8953
 4.8946        -.1161288E-03   1               4.8956
 4.8953         .5838711E-03   1               4.8961
 4.8944        -.3161288E-03   1               4.8961
 4.8945        -.2161289E-03   1               4.8966
 4.8949         .1838711E-03   1               4.8969
 4.8944        -.3161288E-03   1               4.8971
 4.8942        -.5161288E-03   1               4.8986
 4.8932        -.1516129E-02   1               4.8988
```

Bullseye Capacitor Stability Test Summary Table

Condition	Serial No.	Mean (pf)	Std. Dev. (pf)	Precision (36%)	N	T (K)	ρ (gm/liter)
Liquid	2	5.9850	±0.00116	±0.058	32	19.66	71.457
	3	5.9832	±0.00088	±0.044	30	19.60	71.522
	4	5.9827	±0.00179	±0.059	31	19.63	71.440
Gas (cold)	2	4.8830	±0.00279	±0.171	32		
	3	4.8746	±0.00343	±0.211	29		
	4	4.8773	±0.00139	±0.085	31		
Gas (warm)	2	4.9034	±0.00155	±0.095	32	256 +	
	3	4.8889	±0.00039	±0.024	30	256 +	
	4	4.8947	±0.00165	±0.100	31	256 +	

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